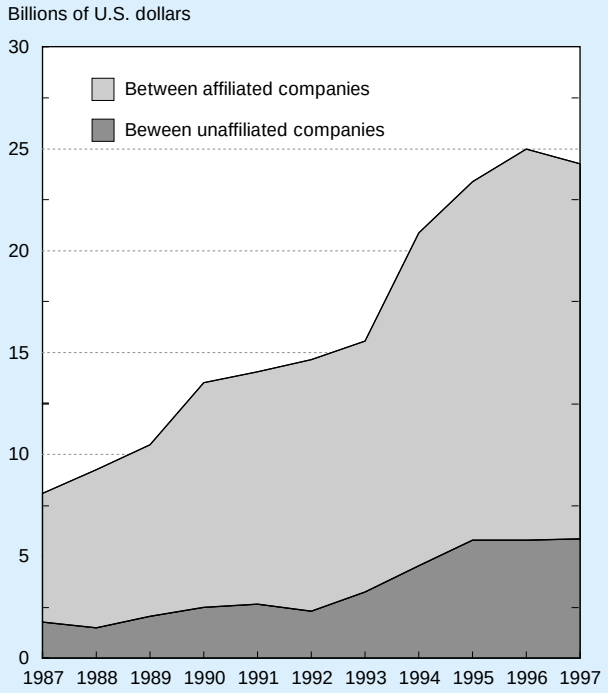
Figure 7-15.
U.S. trade balance in intellectual property



See appendix table 7-7. *Science & Engineering Indicators – 2000*

nearly six times U.S. firm payments (imports) to Asia. As previously noted, Japan and South Korea were the biggest customers for U.S. technology sold as intellectual property. Together these countries accounted for more than 55 percent of total receipts in 1997.

The U.S. experience with Europe has been very different from that with Asia. Over the years, the balance of U.S. trade with Europe in intellectual property has bounced back and forth, showing either a small surplus or deficit until 1995. In 1995, United States–Europe trade produced a considerably larger surplus for the United States compared with earlier years, the result of a sharp decline in U.S. purchases of technical know-how from the smaller European countries that year. The following year also showed a large surplus, but this time it was driven by a jump in receipts from the larger European countries. The latest data (1997) show receipts from the larger European countries dropping back to pre-1996 levels, which caused a considerably smaller surplus from U.S. trade with Europe in intellectual property in 1997.

Foreign sources for U.S. firm purchases of technical know-how have changed somewhat over the years, with increasing amounts of coming from Japan. About one-fourth of 1997 U.S. payments for technology sold as intellectual property were made to Japanese firms. Europe still accounts for slightly more than 60 percent of the foreign technical know-how purchased by U.S. firms with France, Germany, and the United Kingdom being the principal European suppliers. Since 1992, however, Japan has been the single largest foreign supplier of technical know-how to U.S. firms.

International Trends in Industrial R&D

In high-wage countries like the United States, industries stay competitive in a global marketplace through innovation (Council on Competitiveness 1999). Innovation can lead to better production processes and better-performing products (for example, those that are more durable or more energy efficient). It can thereby provide the competitive advantage high-wage countries require when competing with low-wage countries.

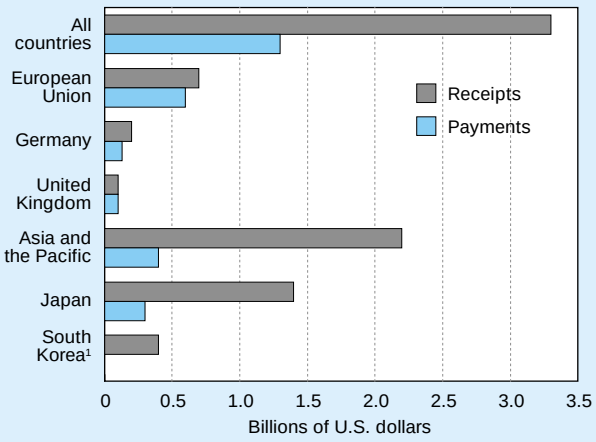
R&D activities serve as an incubator for the new ideas that can lead to new products, processes, and industries. Though they are not the only source of new innovations, R&D activities conducted in industry-run laboratories and facilities are associated with many of the important new ideas that have helped shape modern technology.

U.S. industries that traditionally conduct large amounts of R&D have met with greater success in foreign markets than less R&D-intensive industries and have been more supportive of higher wages for their employees.[9] Moreover, trends in industrial R&D performance serve as leading indicators of future technological performance. This section examines these R&D trends, focusing particularly on growth in industrial R&D activity in the top R&D-performing industries of the United States, Japan, and the European Union.[10]

[9]See the section, "U.S. Technology in the Marketplace," earlier in this chapter for a presentation of recent trends in U.S. competitiveness in foreign and domestic product markets.

[10] This section uses data from the OECD's Analytical Business Enterprise R&D database (Paris, April 1999) to examine trends in national industrial R&D performance. This database tracks all R&D expenditures (both defense- and nondefense-related) carried out in the industrial sector, regardless of funding source. For an examination of U.S. industrial R&D by funding source and type of research performed, see chapter 2 in this volume, "U.S. and International Research and Development: Funds and Alliances."

Figure 7-16.
U.S. royalties and fees generated from the exchange of industrial processes between unaffiliated companies: 1997



[1]Data withheld to avoid disclosing operations of individual companies.
See appendix table 7-8. *Science & Engineering Indicators – 2000*

Overall Trends

The United States has long led the industrial world in the performance of industrial R&D. During the past two decades, as technology has become more closely associated with firm success in the global marketplace, other advanced economies have put more of their resources into R&D and have increased their industrial R&D performance at an annual growth rate that exceeds that in the United States. (See the sidebar, "Economists Estimate Rates of Return to Private R&D Investment.")

Consequently, the U.S. share of total industrial R&D performed by all OECD member countries fell between 1973 and 1990. (See figure 7-17.) Despite this decline, the United States remained the leading performer of industrial R&D by a wide margin, even surpassing the combined R&D of the 15-nation European Union. For its part, Japan—in keeping with its belief in the economic benefits of investments in R&D—rapidly increased R&D spending in the 1970s and 1980s that led to a large increase in its share of total OECD R&D by 1990. Data for 1996 show U.S. industrial R&D performance accounting for 45.3 percent of total R&D performed in OECD countries, EU performance for 26.4 percent, and Japanese performance for 18.8 percent.

R&D Performance by Industry

The United States, the European Union, and Japan represent the three largest economies in the industrial world and compete head to head in the international marketplace. An analysis of R&D data provides some explanation for past successes in certain product markets, provides insights into future product development, and signals shifts in national technology priorities.[11]

United States

R&D performance by U.S. industry followed a pattern of rapid growth during the 1970s, which accelerated during the early 1980s. That growth pattern stalled during the latter part of the decade and into the 1990s. When adjusted for inflation, U.S. industrial R&D performance shows a period of annual declines, beginning in 1992, that continued through 1994. Since then, U.S. industry has ratcheted up its performance R&D with the latest data showing annual increases of about 7 percent above inflation in both 1995 and 1996. (See figure 7-18 for the top five categories of R&D performance.)

Throughout the 1970s and 1980s, the U.S. aerospace industry was consistently the largest performer of R&D, accounting for 20–25 percent of total R&D performed by U.S. industry. The industry manufacturing electronics equipment and components was the next largest performer during this period, accounting for 11–16 percent. During the 1990s, the Nation's R&D emphasis shifted in several ways. The aerospace industry's share declined while the share for the industry manufacturing communications equipment increased. In 1996, the communications equipment industry became the top R&D performer in the United States. In many ways the more important change to emerge in the 1990s was the rise in R&D performance by U.S. service sector industries. The service sector's share of U.S. industrial R&D performance jumped from 14 percent in 1989 to 19 percent in 1990, and then rose to 24 percent in 1991 and 1992. Since 1992, the pace of R&D performance in the U.S. service sector has slowed somewhat, and R&D performance in the manufacturing sector has picked up. In 1996, manufacturing industries performed nearly 81 percent of total U.S. industrial R&D, while the share attributed to service sector industries dropped to about 19 percent.

Japan

During the 1970s, R&D performance in Japanese industries grew at a higher rate than in the United States. Japanese industry continued to expand its R&D spending rapidly through 1985, more than doubling the annualized growth of the previous decade. Japanese industrial R&D spending slowed somewhat during the second half of the 1980s, but the country still led all other industrial nations in terms of average annual growth in industrial R&D. Unlike the generally declining trend observed for manufacturing industries in the United States, Japanese manufacturing industries consistently accounted for about 95 percent of all R&D performed by Japanese industry. R&D in Japanese service sector industries appears to have accelerated during the early 1990s, but that trend did not continue in 1995 and 1996. The country's industrial R&D continues to be dominated by the manufacturing sector. (See figure 7-19.)

An examination of growth trends for the top five R&D-performing industries in Japan reflects that country's long-standing emphasis on communications technology (including consumer electronics and all types of audiovisual equipment). This industry was the leading performer of R&D throughout the period reviewed. Japan's motor vehicle industry was the third leading R&D performer in 1973, but rose to number two in 1980 and has retained that position nearly every year through 1996. Japanese auto makers earned a reputation for high quality and value during these years, which earned them increasingly larger shares of the global car market.

Electrical machinery producers are also among the largest R&D performers in Japan, and they have maintained high R&D growth throughout the period examined. In 1994, this industry had moved past the motor vehicle industry to become Japan's second leading R&D-performing industry before falling back to its traditional third position in 1995 and 1996. In comparison, the U.S. electrical machinery industry's ranking among the top R&D performers in the United States has dropped steadily since 1973.

The European Union

Like Japan and the United States, manufacturing industries perform the bulk of industrial R&D in the 15-nation European Union. The European Union's industrial R&D appears to be somewhat less concentrated in the mid 1990s than in the United States, but more so than in Japan. Manufactur-

[11]Industry-level data are occasionally estimated here in order to provide a complete time series for the 1973–96 period.

Economists Estimate Rates of Return to Private R&D Investment

The study of economic returns to R&D investment has developed over the past 30 years. Although estimates of the rates of return differ, the leading researchers in the field agree that R&D has a significant and important positive effect on economic growth and the overall standard of living.

It should be noted, however, that the precise magnitude of these returns cannot be measured without the use of simplifying assumptions in the analysis. A recent survey article by Nadiri (1993) examined 63 studies in this area published by prominent economists, mostly in reference to the United States, but also in reference to Japan, Canada, France, and Germany. Looking at the results of these studies, he concluded that R&D activity renders, on average, a 20- to 30-percent annual return on private (industrial) investments. (See text table 7-2.) This is not to say that every research project has a high, or even a positive, rate of return. Rather, portfolios of scientific research projects selected for analysis have the rates of return cited above. Since they reflect average returns to a selected group of projects, these returns cannot be applied to aggregate R&D expenditures. It should also be pointed out that the more basic the research, the harder it is to evaluate the returns to R&D.

Returns to society overall are estimated to be even higher. Society often gains more from successful scientific advancements than does the organization conducting the research. Therefore, there are two rates of return: the private rate of return, which is based on the expenses incurred and profits made by the company conducting the research, and the social rate of return, which is based on the overall effects on society, including the firm conducting the research.

Recent academic research has also played a key role in enabling technological advances in the private sector. Studies show that approximately 10 percent of the new products and processes developed by firms depend on recent academic research and that the association between academic and industrial research has been strongest in medicine and electronics. (See text table 7-3.) Still, association should not be construed as causation. These studies do not rigorously establish a causal relationship between university research and industrial patents. In fact, that relationship may be reversed, to some extent, by feedback mechanisms, in which industrial patents encourage further research by local universities.

Note: This information was first presented in chapter 8 of *Science and Engineering Indicators 1996*.

Text table 7-2.
Estimated annual rates of return to R&D expenditures in the United States according to various economic studies

Author(s) and year of study	Rate of return[a]
Firm-level studies	
Link (1983)	3
Bernstein-Nadiri (1989b)	7
Schankerman-Nadiri (1986)	13
Lichtenberg-Siegel (1991)	13
Bernstein-Nadiri (1989a)	15
Clark-Griliches (1984)	19
Griliches-Mairesse (1983)	19
Jaffe (1986)	25
Griliches (1980)	27
Mansfield (1980)	28
Griliches-Mairesse (1984)	30
Griliches-Mairesse (1986)	33
Griliches (1986)	36
Schankerman (1981)	49
Minasian (1969)	54
Industry-level studies	
Terleckyj (1980)	0[b]
Griliches-Lichtenberg (1984a)	4
Patel-Soete (1988)[c]	6
Mohnen-Nadiri-Prucha (1986)	11
Terleckyj (1974)	15
Wolff-Nadiri (1987)	15
Sveikauskas (1981)	16
Bernstein-Nadiri (1988)	19
Link (1978)	19
Griliches (1980)	21
Bernstein-Nadiri (1991)	22
Scherer (1982, 1984)	36

[a]For studies for which Nadiri (1993) reports a range of possible returns, the midpoint of that range is provided in this table.

[b]Not significantly different from zero in a statistical sense. This result, however, may be a reflection of limitations in the quantity of data used in the study.

[c]Economy-level study (all industries grouped together).

SOURCE: M.J. Nadiri, "Innovations and Technological Spillovers," Working Paper No. 4423 (Cambridge, MA: National Bureau of Economic Research, 1993).

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Text table 7-3.
Percentage of new products and processes that were dependent on academic research, for selected industries in the United States: 1975–85

Industry	Percent dependent, at least partially, on recent academic research for their timely development		Percent developed with "very substantial aid" from recent academic research	
	Products	Processes	Products	Processes
Information processing	11	11	17	16
Electronics	6	3	3	4
Chemical	4	2	4	4
Instruments	16	2	5	1
Pharmaceuticals	27	29	17	8
Metals	13	12	9	9
Petroleum	1	1	1	1
Average	11	9	8	6

SOURCES: E. Mansfield, "Academic Research and Industrial Innovations," Research Policy 1991, 20:1–12; and E. Mansfield, "Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing," *The Review of Economics and Statistics* 77(1): 55–65, 1995.

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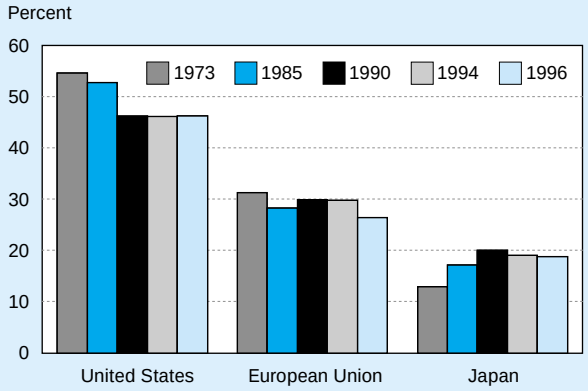
Figure 7-17.
Shares of total industrial R&D in OECD countries

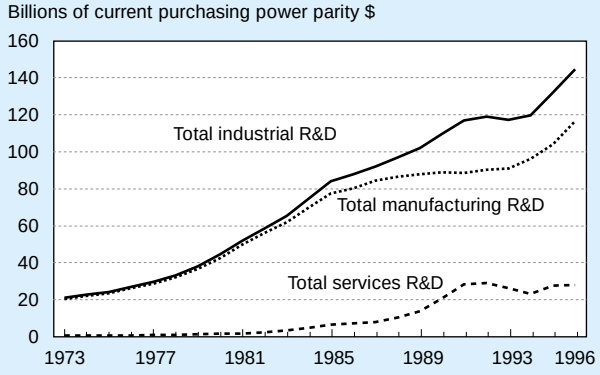


SOURCE: The Organisation for Economic Co-operation and Development, Analytical Business Enterprise R&D database (Paris: 1997). *Science & Engineering Indicators – 2000*

ers of electronics equipment and components, motor vehicles, and industrial chemicals have consistently been among the top five performers of industrial R&D in the European Union. (See figure 7-20.) In 1995, Germany led the European Union in the performance of motor vehicle and industrial chemical R&D, while France led in industrial R&D performed by communications equipment (consumer electronics and all types of audiovisual equipment) manufacturers, and the United Kingdom in pharmaceuticals.

R&D performed by the European Union's service sector has doubled since the mid-1980s, accounting for about 11 percent of total industrial R&D performed by 1995. Large increases in service sector R&D are apparent in many EU countries, but especially in the United Kingdom (19.6 percent of its industrial R&D in 1995), Italy (15.3 percent), and France (10.0 percent).

Figure 7-18.
U.S. industrial R&D performance: 1973–1996

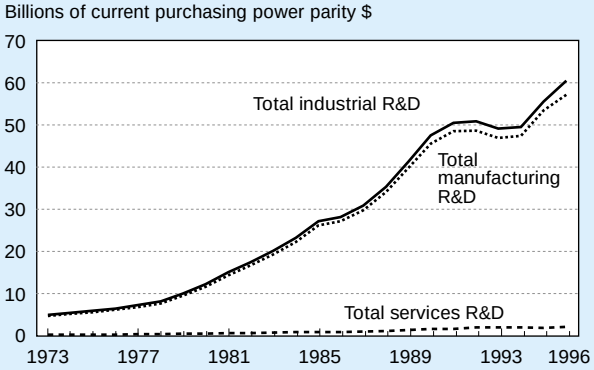


Top industrial R&D performers and their share of total industrial R&D

1976		1986		1996	
Aerospace	23.5%	Aerospace	24.0%	Services (total)	19.5%
Elec. equip. & components	12.1%	Elec. equip. & components	15.6%	Elec. equip. & components	13.2%
Motor vehicles	10.3%	Office machinery & computers	11.2%	Aerospace	11.2%
Office machinery & computers	8.9%	Motor vehicles	11.1%	Motor vehicles	11.1%
Elec. machinery	8.8%	Services (total)	8.5%	Office machinery & computers	8.8%

See appendix table 7-9. *Science & Engineering Indicators – 2000*

Figure 7-19.
Japanese industrial R&D performance: 1973–1996

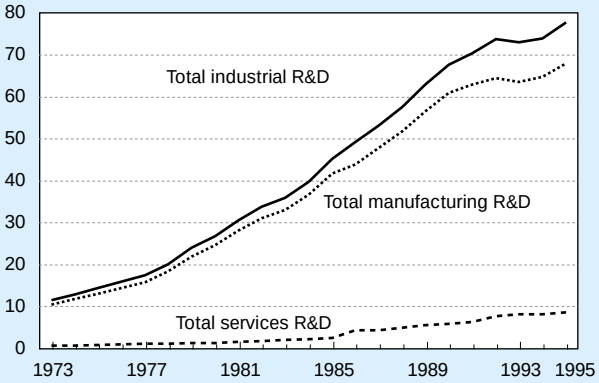


Top industrial R&D performers and their share of total industrial R&D

1976		1986		1996	
Elec. equip. & components	14.9%	Elec. equip. & components	18.1%	Elec. equip. & components	16.1%
Industrial chemicals	12.9%	Motor vehicles	13.1%	Motor vehicles	12.8%
Motor vehicles	11.5%	Industrial chemicals	10.5%	Electrical machinery	10.9%
Elec. machinery	11.0%	Electrical machinery	10.1%	Industrial chemicals	9.2%
Nonelectrical machinery	10.0%	Nonelectrical machinery	8.3%	Nonelectrical machinery	8.7%

See appendix table 7-10. *Science & Engineering Indicators – 2000*

Figure 7-20.
EU 15 industrial R&D performance: 1973–1995



Top industrial R&D performers and their share of total industrial R&D

1976		1986		1995	
Elec. equip. & components	15.6%	Elec. equip. & components	17.0%	Motor vehicles	14.4%
Industrial chemicals	13.3%	Industrial chemicals	11.3%	Elec. equip. & components	14.0%
Aerospace	12.5%	Motor vehicles	11.1%	Services (total)	11.2%
Motor vehicles	10.0%	Aerospace	10.8%	Pharmaceuticals	10.0%
Electrical machinery	8.1%	Electrical machinery	8.0%	Industrial chemicals	9.6%

NOTE: 1996 data are unavailable.

See appendix table 7-11. *Science & Engineering Indicators – 2000*